TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 375

EFFECT OF ROUGHNESS ON PROPERTIES OF AIRFOILS

By O. Schrenk

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The first group of a large series of contemplated experiments on the effect of roughness on airfoils was intended to show the effect of great roughness on airfoils of various sizes and attitudes.

The wing tested (profile No. 449) had an area of $0.3 \times 1.2 = 0.36\ m^2$ (3.88 sq.ft.). The roughening was produced by 0.5 mm (0.02 in.) iron-wire gauze having 38 square meshes to 10 cm (3.937 in., i.e., nearly 10 meshes to an inch). Its maximum elevations above the airfoil surface were about 1.2 mm (0.047 in.). The gauze was uniform throughout the whole span, one set of wires being parallel with the edges of the airfoil. Figs. 3-4 show the location of the gauze and Figs. 1-2 the experimental results.**

The testing of an airfoil with a rough pressure (lower) side has already been described in the First Göttingen Report, p. 69. The results then obtained are verified here (curve III in Figs. 1-3), namely, increased lift (in comparison with a smooth wing) for the same angle of attack in the region of small

*"Oberflächenrauhigkeiten auf Tragflügeln," from "Vorläufige Mitteilungen der Aerodynamischen Versuchsanstalt zu Göttingen." No. 4.

**The closed curves enclose measuring points of the same, or nearly the same angle of attack of the different polar curves.

and medium lift coefficients; nevertheless, more unfavorable lift-drag ratios throughout, on account of the simultaneously greater profile drag; and somewhat smaller maximum lift. A constant increase in the profile drag is very evident from 0° angle of attack downward, while it remains nearly constant at positive angles. This is connected with the fact that the pressure side gradually begins to assume suction-side properties at negative angles of attack, as is confirmed by a glance at the pressure distribution curves in the Second Göttingen Report, p. 43 ff. The region of pressure increase behind the maximum suction, usually characteristic for the suction side, here produces a thickening of the boundary layer and detachments of the flow, with the resulting large profile drag.

The abeve-mentioned lift increase at moderate c_a values is due to increased circulation, i.e., to a greater downward component of the velocity behind the airfoil. The latter is due to the fact that the pressure-side flow is retarded by the junction of the two currents at an acute angle behind the trailing edge.

The rough suction side produces the above-mentioned great increase in drag, as well as a considerable decrease in lift. It is obviously much more important for the suction side to be smooth than for the pressure side. This also follows from the fact that the polar curve of the entirely rough profile (curve II) differs but little from the polar curve of the profile with only the suction side rough.

The curves V-VII are for a partially rough suction side. Curve VII (roughness near the trailing edge) does not differ noticeably from curve I, as is likewise the case for the corresponding moment curves. It is otherwise for roughnesses at the middle of the chord (VI) and near the leading edge (V). Here the differences are noticeable, and the profile is just as much more sensitive to roughness on the suction side, as it is farther forward.

This variation in the sensitiveness is due to great variation in the thickness of the boundary layer. The elevations of the gauze near the leading edge, where the boundary layer is vanishingly thin, cause disturbances which reach far into the potential flow, while farther back (at least for the index values of our experiments) they are entirely enveloped in the thicker boundary layer.* Moreover, the sensitiveness of a potential flow is the greatest where the kinetic energy is the greatest, at approximately the position of the roughness V.

If a distinction is made, inside the boundary layer, between the very thin laminar portion close to the airfoil and a much thicker turbulent portion between the laminar and the potential flows, then the tested roughness is in any case, so great that it is nowhere entirely submerged in the laminar portion of the boundary layer. Lastly, it is to be noted that the total thick-

* Regarding the thickness of the boundary layer on the airfoil, cf. Ackeret "Zeitschrift für Flugtechnik und Motorluftschiffahrt," 1925, p.46.

ness of the boundary layer diminishes relatively as the index value increases,* so that a somewhat greater sensitiveness is probably to be expected for an airplane, when the roughness elevations, in comparison with a corresponding linear dimension (e.g., the chord) are of equal magnitude.

With restriction to great roughness, airfoil shapes not differing too much, and similar index values, the much greater sensitiveness of the suction (upper) side, in comparison with the pressure (lower) side has been demonstrated, as likewise also the great increase of the sensitiveness on the suction side from the trailing edge toward the leading edge.

We expect to make further experiments on the effect of the profile shapes amd smaller roughnesses, as likewise of other kinds of disturbances.

* Cf. Von Karman, "Zeitschrift für angewandte Mathematik und Mechanik," 1921, p. 243, where it is calculated, however, only for flat plates.

Translation by Dwight M. Miner,
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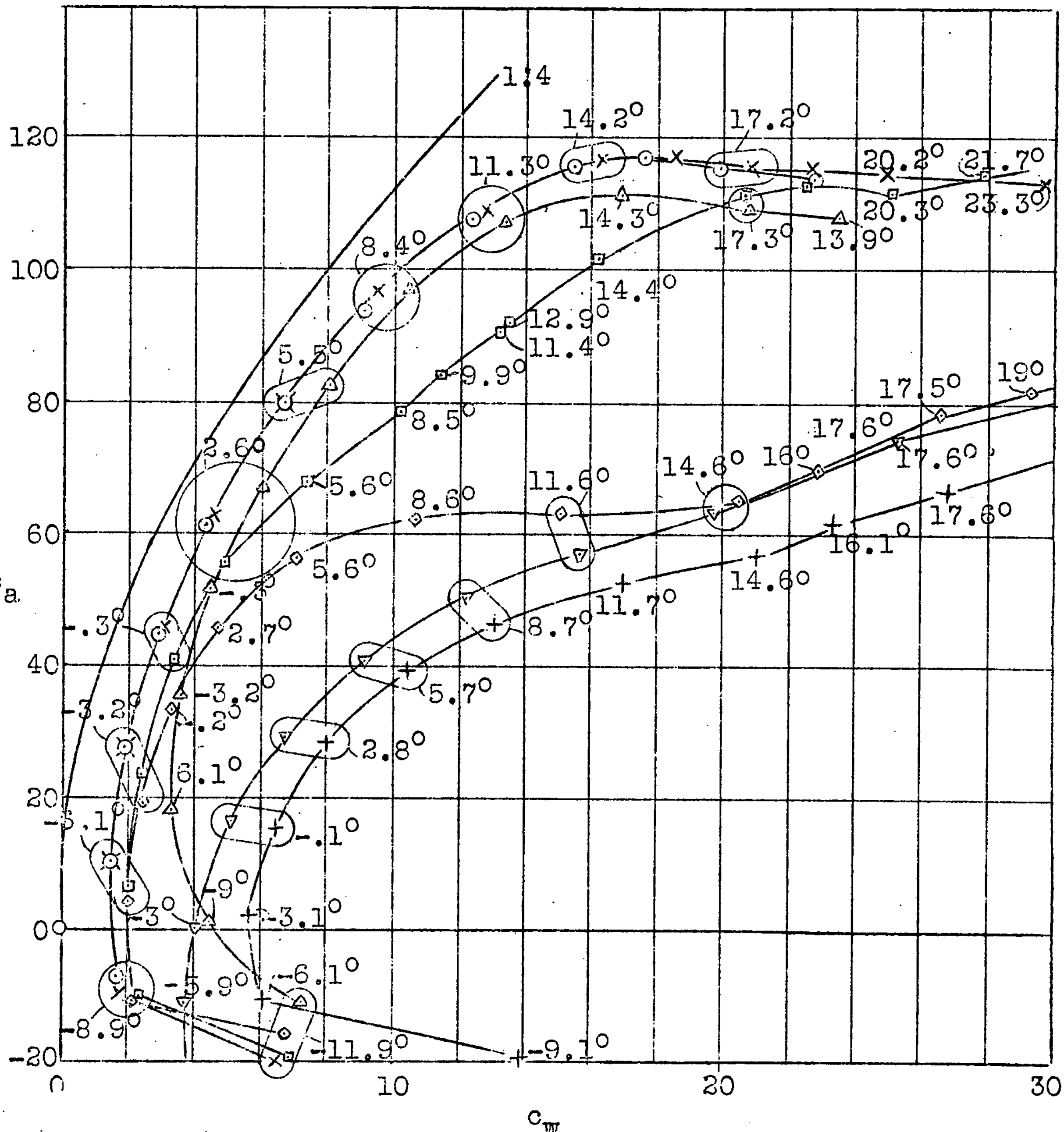

I ——⊙—— Airfoil perfectly smooth.
II ——+—— Airfoil rough on both sides.
'III ——△—— Pressure side rough.
' IV ——▽—— Suction side rough.
"V ——◇—— Rough strips on suction side near leading edge.
"VI ——□—— Rough strips on suction side near middle of chord.
"VII ——×—— Rough strips on suction side near trailing edge.

' See Fig.3.
" See Fig.4

Fig.1

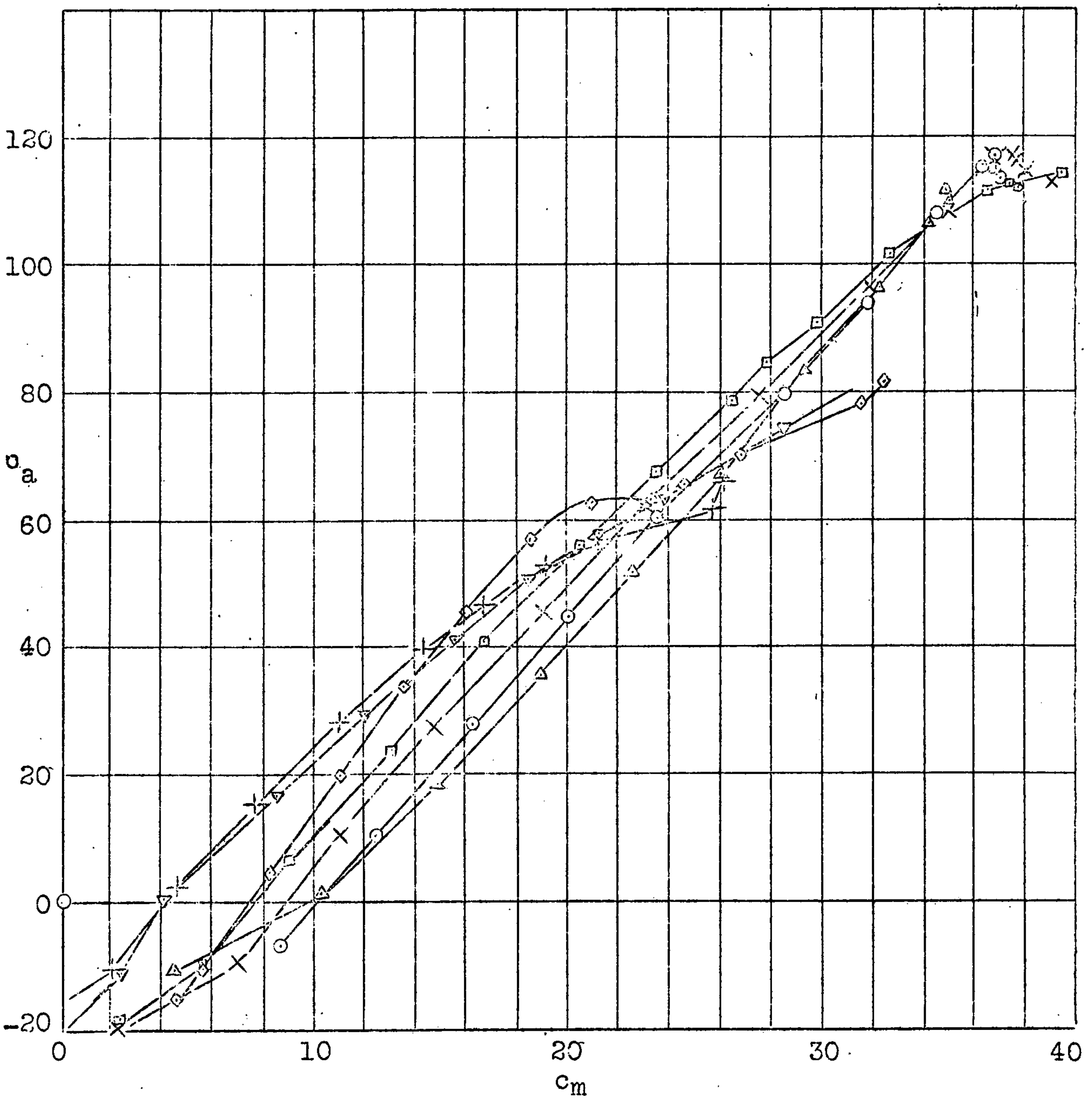

Fig.2

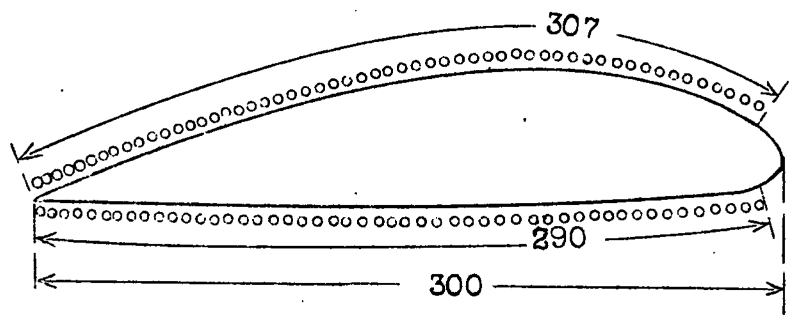

Fig.3

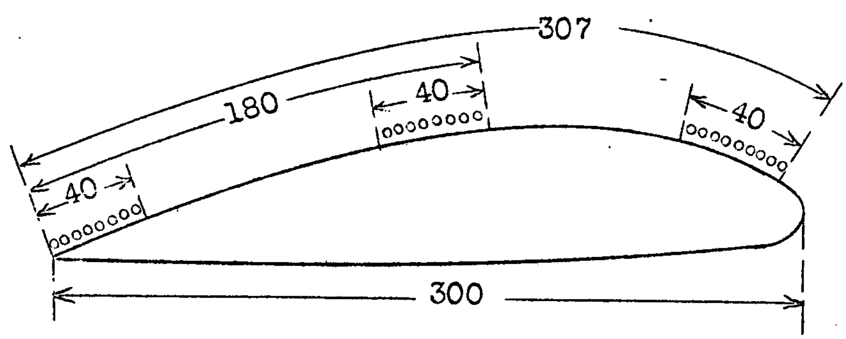

Fig.4